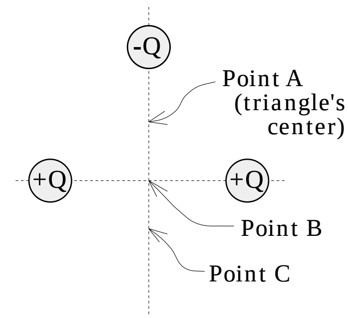
MULTIPLE CHOICE SOLUTIONS--E&M

TEST III

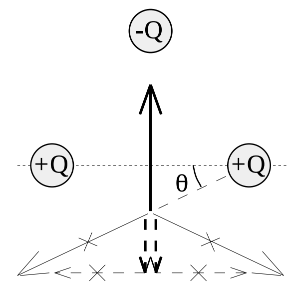


1.) Given the charge configuration shown to the right, where will the electric field be approximately zero?

a.) Point A. [An electric field is defined as the force/unit charge available at a particular point due to the presence of some field-producing charge configuration. The direction of the field is defined as the direction a positive test charge would accelerate if placed in the field at the point of interest. At Point A, a positive test charge will be pulled in the +j direction by the -Q charge at the top of the system and pushed in the same direction due to repulsion from the two +Q charges at the bottom. That means that a positive test charge will, indeed, accelerate if put in the field at Point A, and the electric field at that point is not zero. This response is false.]

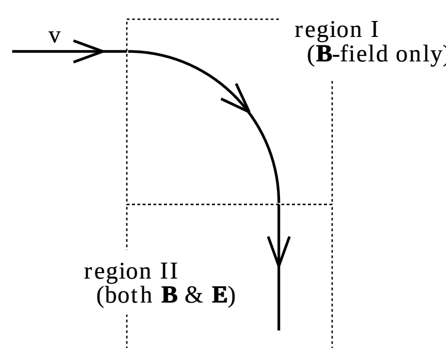
b.) Point B. [The net electric field at Point B will be in the +j direction. How so? The fields due to the two +Q charges will cancel one another out, and the field due to the remaining -Q charge will be in the +j direction (a positive test charge will be attracted to -Q, hence the direction of the electric field due to -Q will be upward). The electric field at this point is not zero, and this response is false.]

c.) Point C. [The net field due to the two +Q charges will be in the -j direction. The field due to the -Q charge will be in the +j direction. It is possible that the net field could be zero. How so? The +Q charges are closer to the point than the -Q charge. Nevertheless, the x-components of those two charges could add to zero, and the y-components would not be terribly large due to the angle (each charge will contribute a field $E_y = E \sin \theta$, where θ is shown in the sketch) . Added together, those E_y terms could cancel the field produced by -Q yielding no net electric field at C. This response is true.]



x-components add to zero,
y-components are $E \sin \theta$ each

d.) There is a point where E = 0, but it's not along the y-axis. [Due to the symmetry of the situation, this will never be true. That is, the zero electric field point must be along the y-axis. This response is false.]



2.) A positive charge moves with a known velocity v into region I in which an unknown B-field exists. It accelerates as shown in the sketch, then enters region II in which there exists not only B but also an unknown electric field E. With that:

a.) The magnitude of the magnetic field is mv/qR, where m is the mass of the charged particle and R is the radius of the charge's motion. [Utilizing the fact that the magnetic force is centripetal, we can use Newton's Second Law to write $qvB = m(v^2/R)$, or $B = mv/qR$. This response is true. Are there other true responses?]

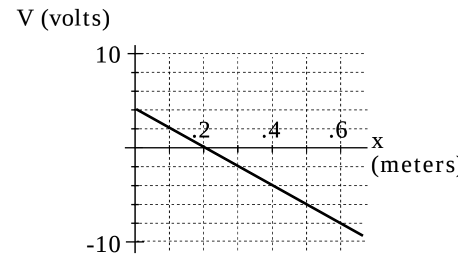
b.) The electric field is related to the magnetic field by E = B/v. [In region II, the magnetic force must be equal and opposite the electric force, or qvB = qE. From this, we get the relationship E = vB and this response is false.]

c.) The magnetic force in this situation is a conservative force. [Because magnetic forces are always centripetal, the total work done by a magnetic force will always be zero no matter what path is taken for the body's motion. As path independence is the hallmark of conservative forces, the magnetic force must be conservative and this statement is true.]

d.) Both a and b. [Nope.]

e.) Both a and c. [This is the one.]

f.) None of the above. [Nope.]



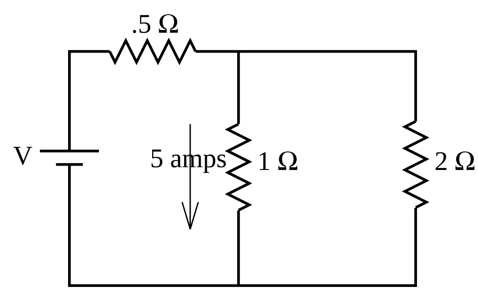
3.) An electrical potential field along the x-axis is defined by the graph shown. The electric field is:

a.) Constant and positive at x = .2 meters. [We know that $\boldsymbol{E} = -\nabla V$. What this tells us is that in one-dimension, the derivative of the electrical potential function (i.e., its slope) is equal to minus the electric field function. In this case, the slope is always negative, which means that the electric field will always be positive (remember the negative sign in $\boldsymbol{E} = -\nabla V$). Also, as the slope is a constant, the electric field is constant. This response is not only true for x = .2 meters, it is true for all x's.]

b.) Positive and non-linear. [A linear electric field function will produce a non-linear electrical potential function, not vice versa. This response is false.]

c.) Negative and linear. [Nope.]

d.) Negative and non-linear. [Nope.]



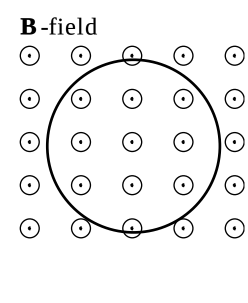
4.) Consider the circuit shown. How much current is drawn from the battery?

a.) 15 amps. [There are a number of ways to do this, including the ponderous use of Kirchoff's Laws. The simplest way is to just use your head. We know that the voltage across the 1 Ω resistor and the 2 Ω resistor is the same. Under that circumstance, the amount of current through the 2 Ω resistor will be half as much as the current through the 1 Ω resistor (the greater the resistance for a given voltage, the less the current). As the current through the 1 Ω resistor is 5 amps, the current through the 2 Ω resistor must be 2.5 amps and the total current into the parallel combination must be 7.5 amps. This is the current drawn from the power supply. Note that if you thought the current through the 2 Ω resistor was twice that through the 1 Ω resistor, you got the incorrect answer presented in this response.]

b.) 7.5 amps. [This is the one.]

c.) 3.3 amps. [If you combined the parallel combination of resistors, yielding an equivalent resistance of (2/3) Ω, then incorrectly tried to multiply that by the current through the 1 Ω resistor to get . . . whatever . . . you got this incorrect response.]

d.) None of the above. [Nope.]



5.) A 50 turn coil whose cross-sectional area is 2 square meters and whose resistance is R = 12 Ω faces a uniform B-field coming out of the page which doubles at a constant rate every 10 seconds. At t = 0, the magnetic field intensity is

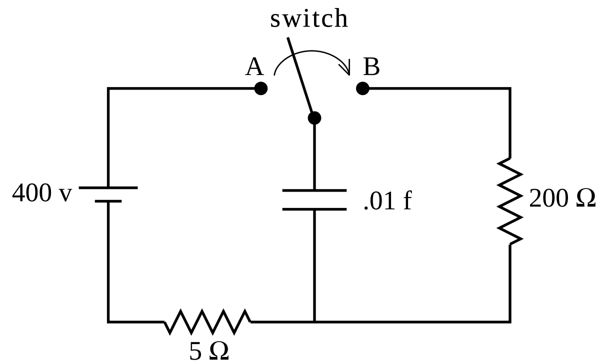
.25 teslas. The magnitude of the magnetic flux set up through the coil at t = 5 seconds will be:

a.) .75 teslas. [If the magnetic field doubles every 10 seconds, and if it starts out at t = 0 at .25 teslas, the magnetic field at t = 5 seconds must be .375 teslas. In situations in which the magnetic field vector, area vector, and angle between the two are all constant, the magnetic flux is defined as B·A. With the angle between B and A being 0^o, the cosine is 1 and the dot product becomes BA. At t = 5 seconds, the magnetic flux will, therefore, be BA = (.375 teslas)(2 $meter^2$) = .75 webers. Unfortunately, the units of this response are wrong and this response is false.]

b.) .75 webers. [This has the correct units and is the true response.]

c.) 1.5 tesla·$meters^2$. [Although the units are correct, this response is false.]

d.) None of the above. [Nope.]



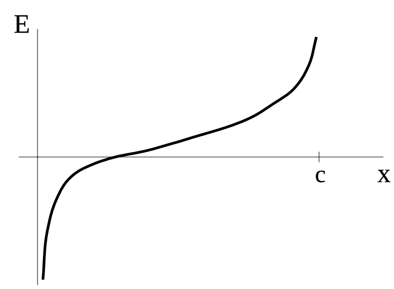
6.) In the system shown, the switch has been set on contact A for a long time. At t = 0, the switch flips from contact A to contact B. How long will it take for the capacitor to dump approximately 90% of its charge across the resistor?

a.) (1/4) second. [It takes a little more than two time constants for a capacitor to dump 90% of its charge. As one time constant is equal to RC, two time constants will be 2(200 Ω)(.01 f) = 4 seconds. This response is false.]

b.) (1/2) second. [Nope.]

c.) 2 seconds. [Nope.]

d.) 4 seconds. [This is it.]



7.) Charge A is placed at the origin and charge B is placed a distance c units down the +x axis. A graph of the magnitude of the subsequent electric field E between the two is shown to the right.

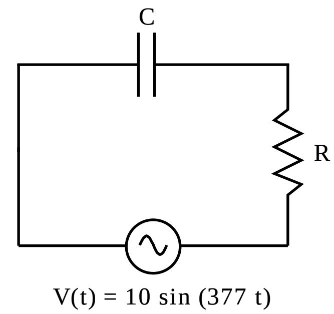
a.) Both charges are positive with charge A being larger in magnitude. [If both charges are positive, there will be a point between the two where the electric field is zero. That is the case here, so we might have a winner. A positive charge A will produce an electric field in its vicinity along the +x axis that will be to the right (in the +x direction). As the field close to the origin in our situation is negative, the field we are dealing with must be made up of two charges that are both negative, and this response is false.]

b.) Both charges are negative with charge A being larger in magnitude. [From above, both charges are, indeed, negative. The question is, which is larger? Looking at the graph, charge B ranges farther than charge A (the two add to zero at a point closer to A and B) which suggests that B is the larger charge. This response is false.]

c.) Charge A is negative while charge B is positive, and charge B is larger in magnitude. [This is the wrong kind of graph for a mixed pair of charges. This response is false.]

d.) Charge A is negative while charge B is positive, and charge B is smaller in magnitude. [This is the wrong kind of graph for a mixed pair of charges. This response is false.]

e.) None of the above. [This is the one.]



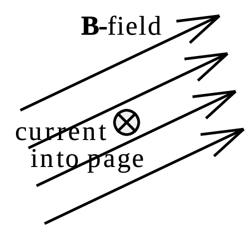
8.) The capacitance of the capacitor in the circuit is 10 nf and the resistance is R = 1000 Ω. If the frequency of the source is changed to 120 cycles/second:

a.) The frequency of the circuit will go down and the impedance will go up. [A power supply whose angular frequency is 377 has a frequency of 60 hertz (do the math--with 377 = $\omega = 2\pi\nu$, the frequency is (377 radians/second)/(2π) = 60 hertz). If the new frequency is 120 hertz, the frequency has gone up and this response is false.]

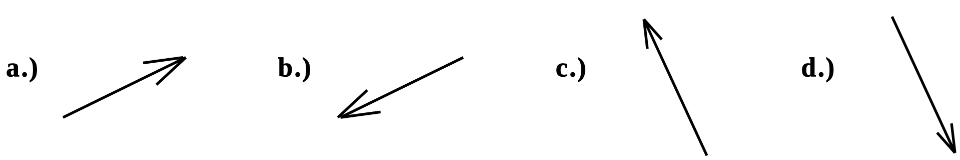
b.) The frequency of the circuit will go down and the impedance will go down. [This is the wrong frequency conclusion. This response is false.]

c.) The frequency of the circuit will go up and the impedance will go up. [The frequency information is correct in this response. What about the second part? There is an easy, quick way of determining this along with a second more expanded but mathematically interesting way available. THE SHORT WAY: Capacitors are high pass filters. That means they are amenable to passing high frequency signals but will not pass low frequency signals. That means that their frequency-dependent resistive nature decreases as the frequency increases (the less resistance to charge flow, the more current you get). As the frequency has increased in the circuit, the resistive nature of the capacitor has decreased and the net impedance in the circuit has decreased. THE MATH WAY: In its most general form, the impedance expression is Z = $\sqrt{R_{net}{}^2 + (X_L - X_C)^2}$ ohms, where X_L = $2\pi\nu L$ ohms (the inductance L has to be in henrys, not mH, etc.) and X_C = $\frac{1}{2\pi\nu C}$ ohms (the capacitance C has to be in farads, not mf or pf, etc.). In this problem there is no inductance. As such, the impedance expression becomes $\sqrt{R_{net}{}^2 + \left(-\frac{1}{2\pi\nu C}\right)^2}$. From the expression, it is obvious that as the frequency increases, which is the case here, the impedance decreases. This response is false.]

d.) The frequency of the circuit will go up and the impedance will go down. [This is the one.]



9.) A wire with current directed into the page sits in a magnetic field as shown. The direction of the force on the wire is best described by which selection?



e.) None of these.

[Commentary: Using F = iLxB, the force direction determined by the right-hand rule matches the direction presented in Response d.]

10.) A very long, charge-filled cylinder of radius a has a Gaussian surface (a cylinder) placed about it. The radius of the Gaussian surface is a (that is, the Gaussian surface is placed directly on top of the charge-filled cylinder's outer surface). For that situation, the net flux through the Gaussian surface is ϕ. The radius of the Gaussian cylinder is then doubled to 2r with everything else held constant. For this new situation, the net flux through the new Gaussian surface will be:

a.) 2ϕ. [The net flux through a Gaussian surface will, according to Gauss's Law, equal Q/ε_o. As the charge inside the Gaussian surface did not change when the radius of the Gaussian surface was doubled, the electric flux should stay the same and this response is false.]

b.) ϕ. [This is the one.]

c.) $\phi/2$. [Nope.]

d.) None of the above. [Nope.]

11.) The capacitance of a capacitor is 120 picofarads. That capacitance is the same as:

a.) $1.2\text{x}10^{-10}$ farads. [A picofarad is 10^{-12} farads. 120 picofarads is $120\text{x}10^{-12}$, or $1.2\text{x}10^{-10}$ farads. This response is true. Are there other true responses?]

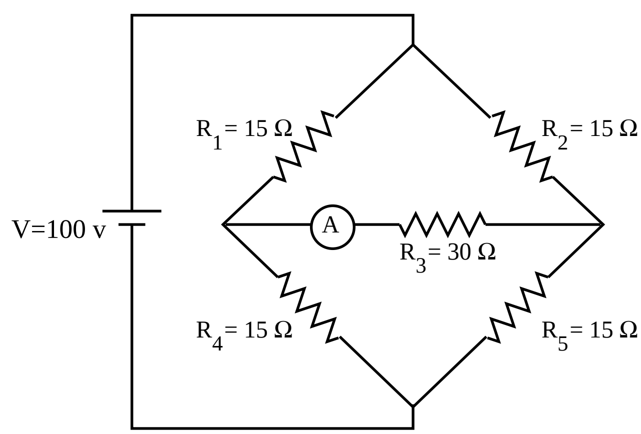
b.) $120\text{x}10^{-6}$ microfarads. [A microfarad is 10^{-6} farads. $120\text{x}10^{-6}$ microfarads is the same as = ($120\text{x}10^{-6}$ farads)(10^{-6}) = $120\text{x}10^{-12}$ farads. This response is true. Are there others?]

c.) 120,000 nanofarads. [A nanofarad is 10^{-9} farads. $120{,}000\text{x}10^{-9}$ = $120\text{x}10^{-6}$, which is not 120 picofarads. This response is false.]

d.) Both a and b. [This is the one.]

e.) Responses a, b, and c. [Nope.]

f.) None of the above. [Nope.]



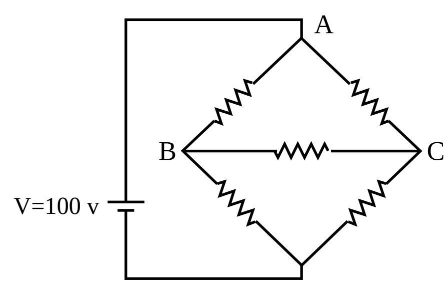
12.) What will the ammeter read?

a.) Zero amps. [This is a tricky problem if you don't see the key. In the auxiliary sketch, the voltage at point A is 100 volts (that point is attached to the high voltage terminal of the battery). Due to the symmetry of the circuit, the voltage drop across R_1 and R_2 will be the same. That means the voltage of points B and C will be the same. With no net voltage difference between B and C, there will be no current through that branch and the current registered by the ammeter will be zero. This response is true.]

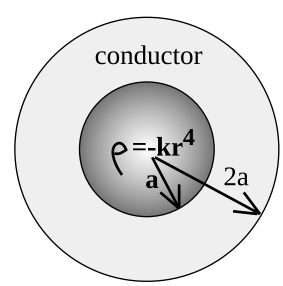
b.) 3.3 amps. [Nope.]

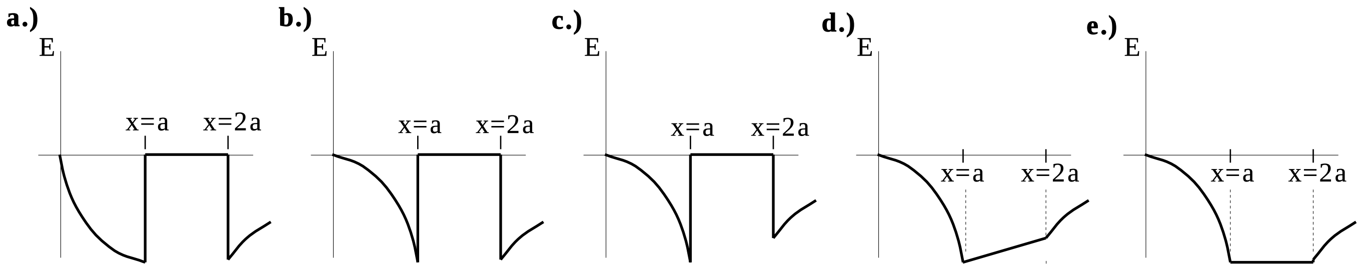
c.) 10 amps. [Nope.]

d.) None of the above. [Nope.]



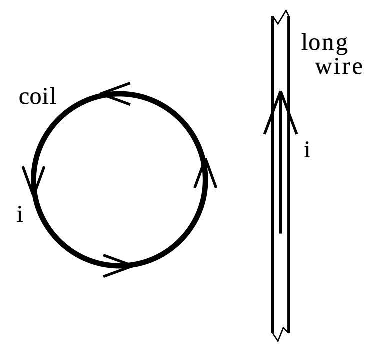
13.) A solid sphere of radius a has a volume charge density of $-kr^4$ shot through it, where k is a constant equal to one with appropriate units. Surrounding the sphere is a conducting shell of outer radius 2a. A graph of the electrical potential field for this configuration looks like:





[Commentary: For a static electric situation, the electric field inside a conductor must be zero (this eliminates graphs d and e). As the charge grows from zero at the origin to a fairly large negative value out toward a, the field growth will start small, then get larger in a negative sense (this eliminates graph a). Finally, if you construct a Gaussian sphere of radius a and a second Gaussian sphere of radius 2a, the two spheres will have the same amount of charge enclosed within them. But because 2a is out farther from the charge's center than is a, the field at 2a will be less than the field at a. In other words, graph b is eliminated and graph c is the true response.]

14.) A coil carrying current i is placed next to a long wire that also carries current i, as shown. Due to its interaction with the long wire's magnetic field:



a.) A net force will be applied to the coil directed toward the right. [To begin with, the long wire will generate a magnetic field that comes out of the page in the region of the loop (the right-thumb rule). As a consequence, there will be forces acting on the coil, but their directions will depend upon which part of the coil they are associated with. At the top, iLxB identifies the force as upward. At the bottom, the force will be downward. On the side nearest the long wire, the force will be to the right. On the side farthest from the long wire, the force will be to the left. The twist is in the fact that the forces on the near and far sides will not be equal, as was the case with the forces at the top and bottom. Why? Because the side nearest the long wire will be in a larger magnetic field and, as a consequence, will feel a force that is larger than the force felt by the far side. In short, there will be a net force to the right. This response is true. Are there other possible true responses?]

b.) A torque will be applied to the coil that motivates it to rotate about an axis parallel to the i direction and in such a way as to have the top of the coil come out of the page. [It is possible to have no net force but still have a torque. All you need are forces that are either in different planes or are not on line, and the forces can add to zero in a particular direction but the torques may not add to zero. In this case, though, all of the forces extend from a common point (the center of the coil) and, as a consequence, produce no torque on the coil at all. This response is false.]

c.) A net force directed toward the left will be applied to the coil. [Nope.]

d.) None of the above. [Nope.]

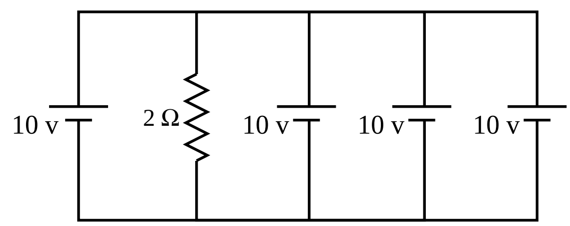
15.) A parallel plate, 50 mf capacitor has 5×10^{-9} coulombs of charge on it. If the plates are .01 meters apart, and if there is a dielectric between the plates whose dielectric constant is 2, what is the electric field between the plates when the dielectric is removed? You can ignore edge effects.

a.) 1×10^{-5} volts/meter. [This has all sorts of twists and turns to it. To begin with, the relationship between a capacitor's capacitance without a dielectric between its plates and that same capacitor with a dielectric is $C_{with} = \kappa_d C_{w/o}$. In this case, the dielectric constant is κ_d = 2, so because our capacitor with dielectric is 50 mf, our capacitor without dielectric will be 25 mf. As we want the electric field without the dielectric, this is the capacitance value to work with. As for the rest of the problem, we know that the voltage across the capacitor is related to the electric field by the relationship $V_{cap} = -\Delta V = \boldsymbol{E} \bullet \boldsymbol{d}$, where V_{cap} is the magnitude of the voltage across the capacitor's plates. This yields the relationship V_{cap} = Ed, where d is the distance between the capacitor plates. We also know that $V_{cap} = Q/C = (5\times10^{-9}$ coulombs)/(25×10^{-3} farads) = $.2\times10^{-6}$ volts. Putting this all together with V_{cap} = Ed, we get an electric field magnitude of E = ($.2\times10^{-6}$ volts)/(.01 m) = 2×10^{-5} volts/meter. If you didn't use the right capacitance (i.e., if you did the problem for the capacitance with the dielectric between the plates), you got this incorrect response.]

b.) 2×10^{-5} volts/meter. [This is the one.]

c.) 4×10^{-5} volts/meter. [Nope.]

d.) None of the above. [Nope.]



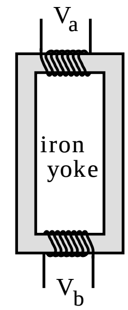
16.) Consider the circuit shown. If four more 10 volt batteries were added in parallel to the power supplies already there:

a.) The net power dissipated by the 2 Ω resistor will increase. [Even though there are lots of 10 volt batteries in the circuit, the voltage across the 2 Ω resistor is 10 volts. Adding four more batteries, all in parallel, will do nothing to change that. In other words, the current through the resistor will continue to be i = V/R = (10 volts)/(2 Ω) = 5 amps, and the power dissipated by the resistor will continue to be i^2R = (5 amps)^2(2 Ω) = 50 watts. This response is false.]

b.) The net power dissipated by the 2 Ω resistor will decrease. [Nope.]

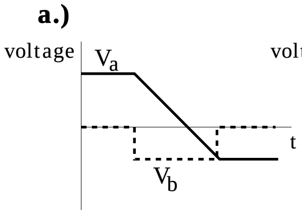
c.) The net power dissipated by the 2 **Ω** resistor will stay the same. [This is the one.]

d.) There is not enough information to tell what the power dissipated by the 2 Ω resistor will do. [Nope.]

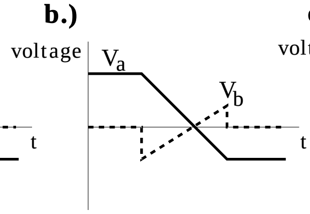


17.) An iron yoke has primary and secondary coils wrapped around each end as shown to the right (the winds ratio is not to scale on the sketch). The voltage V_a across the primary terminal is graphed below along with possible secondary voltage functions (V_b's). Which V_b graph is consistent with the V_a graph?

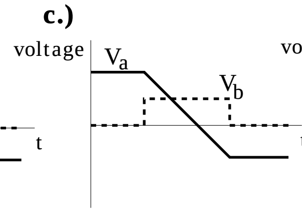
a.)



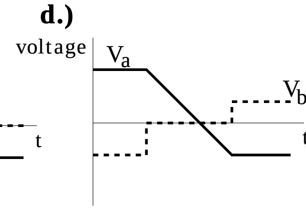
b.)



c.)



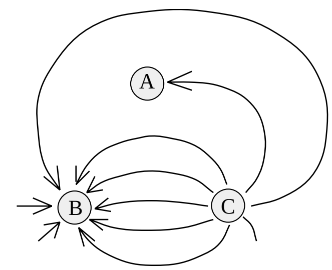
d.)



e.) None of these.

[Commentary: The relationship between primary and secondary coils is simple. When the voltage in the primary changes, an induced voltage is set up in the secondary. That means we will find secondary voltages whenever there are voltage changes in the primary. Furthermore, primary voltage changes that are linear and negative will induce secondary voltages that are constant and negative (and vice versa). Graph a does the trick.]

18.) Three charges produced the anti-symmetric lines shown in the sketch.



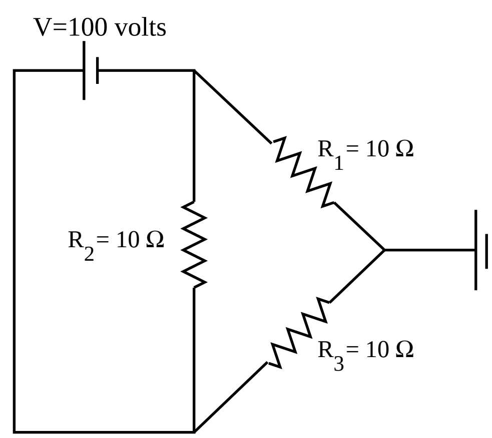
a.) Charge A is negative, charge B is positive, and charge C is negative. Additionally, the magnitude of charge A is smaller than the magnitude of charge B. [Electric field lines proceed from positive charge to negative charge. As field lines terminate at A and B, they must be negative charges. C must be a positive charge. From those observations alone, this response is false.]

b.) Charge A is negative, charge B is negative, and charge C is positive. Additionally, the magnitude of charge A is smaller than the magnitude of charge B. [This has the correct charges. The way we can determine which charge is large, relative to the others, is to pick a point and think how a positive test charge would respond at that point if all the charges were the same size. What actually happens will give you a clue as to relative charge size. In this case, it would appear that A is not a very large charge (if it were, a positive test charge placed on the top electric field line would be pulled into A instead of skirting it). This response is true.]

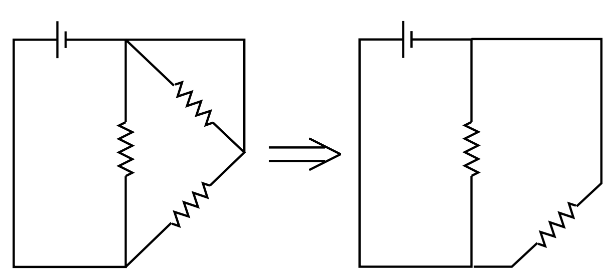
c.) Charge A is negative, charge B is negative, and charge C is positive. Additionally, the magnitude of charge A is bigger than the magnitude of charge B. [Nope.]

d.) None of the above. [Nope.]

19.) Three equal resistors (labeled for discussion purposes) are connected in the grounded circuit as shown.



a.) The current through R_2 will be the same as the current through both R_1 and R_3. [This is a tricky problem. The key is in observing that the absolute electrical potential on the battery side of R_1 is zero (it is attached to the ground of the battery) while the other side of R_1 also has zero voltage as it is attached to a second ground. In other words, the circuit could as well be re-drawn as shown below. With the same voltage on both sides of R_1, that resistor will have no net electric field through it and, hence, no current through it. As such, this response is false.]

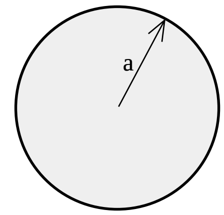


b.) The current through R_1 will be zero. [From above, this response is true. Are there other possible responses that are true?]

c.) The equivalent resistance of this circuit is 5 Ω. [If the voltage drop across R_1 is zero, that resistor and its branch can be removed from the circuit. Noting that the voltage drop across the other two resistors is the same, the circuit can be re-drawn as shown to the right. Being a parallel combination, the equivalent resistance is 5 Ω. This response is true. Are there other possibilities?]

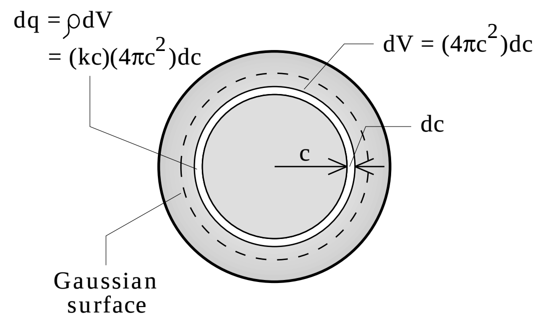
d.) Both b and c. [This is the one.]

e.) None of the above. [Nope.]



20.) A solid sphere of radius a has a volume charge density shot through it of $k_1 r$, where $k_1 = 10^{-10}$ with appropriate units, a = 1 meter, and the constant $\frac{1}{4\pi\varepsilon_o}$ can be approximated as 10^{10} $coul^2/(nt \cdot m^2)$. The electric field at x = a/2 will be:

a.) (1/16) nt/coul. [Unfortunately, this has to be calculated. We need to determine how much charge is inside the Gaussian sphere whose radius r is less than a. Because the charge distribution is not constant, we must define a differential volume dV of radius, say, c, that has a differential thickness of dc. The expression for dV can be determined by noticing that the surface area of the sphere whose radius is c will be $4\pi c^2$, and that multiplying that quantity by the differential thickness dc yields the differential volume dV. Multiplying that expression by the volume charge density function (kr in this case) evaluated at c, and we have all we need to do the Gaussian integral. Jumping almost immediately to the standard form for the left side of Gauss's Law, given that we are working with spherical symmetry, we can write:



$$\int E \bullet dS = \frac{q_{enclosed}}{\varepsilon_o}$$

$$\Rightarrow \quad E(4\pi r^2) = \frac{\int \rho dV}{\varepsilon_o}$$

$$\Rightarrow \quad E = \frac{\int_{c=0}^{r} (k_1 c)(4\pi c^2 dc)}{(4\pi r^2)\varepsilon_o}$$

$$\Rightarrow \quad E = \frac{k_1 \left[\frac{c^4}{4}\right]_{c=0}^{r}}{4\pi\varepsilon_o r^2}$$

$$\Rightarrow \quad E = \frac{k_1}{4\pi\varepsilon_o r^2}\left(\frac{r^4}{4}\right)$$

$$\Rightarrow \quad E = \left(\frac{1}{4}\right)\frac{k_1}{4\pi\varepsilon_o} r^2$$

Spreading things out and evaluating at r = a/2 = 1/2, we get:

$$E = \left(\frac{1}{4}\right)\frac{1}{4\pi\varepsilon_o}k_1 r^2$$

$$\Rightarrow \quad E = \left(\frac{1}{4}\right)\left(10^{10}\right)\left(10^{-10}\right)\left(\frac{1}{2}\right)^2$$

$$\Rightarrow \quad E = \left(\frac{1}{16}\right) \text{nt/coul.}$$

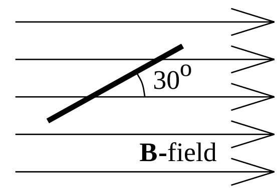
This response is true.]

b.) (1/4) nt/coul. [Nope.]

c.) $(1/16)\text{x}10^{-20}$ nt/coul. [If you inadvertently put $4\pi\varepsilon_o = 10^{10}$ instead of $\frac{1}{4\pi\varepsilon_o} = 10^{10}$, you ended up with this incorrect response.]

d.) None of the above. [Nope.]

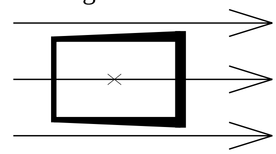
from the side



21.) A rectangular loop whose area is 1 square meter is situated in a magnetic field as shown in the sketch. If the constant B-field's magnitude is .2 teslas, the magnetic flux through the coil will be:

a.) .20 webers, and there will be an induced current set up in the coil due to the presence of the magnetic field. [There is a magnetic flux through this coil, but the flux is not changing so there will be no induced EMF and/or induced current set up in the coil. As such, this response is false.]

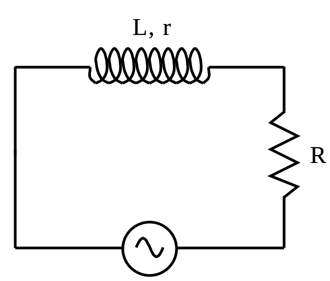
looking from above



b.) .17 webers, and there will not be an induced current set up in the coil due to the presence of the magnetic field. [The second part of this is correct. As for the magnitude of the magnetic flux, that value will be B·A = BA cos θ, where θ is the angle between the magnetic field vector and the area vector. REMEMBER, the direction of the area vector is PERPENDICULAR to the face of the coil. In this case, that angle is the complement of 30^o, or 60^o. As such, the flux calculation becomes (.2 teslas)(1 meter)(cos 60^o) = .1 webers. If you used the wrong angle, you got this incorrect response.]

c.) .10 webers, and there will not be an induced current set up in the coil due to the presence of the magnetic field. [This is the one.]

d.) None of the above. [Nope.]



V(t) = 10 sin (377 t)

22.) The inductance of the inductor in the circuit shown is 10 mH and its resistor-like resistance is 15 Ω. The load resistor is R = 1000 Ω. If the frequency of the source is changed to 120 cycles/second:

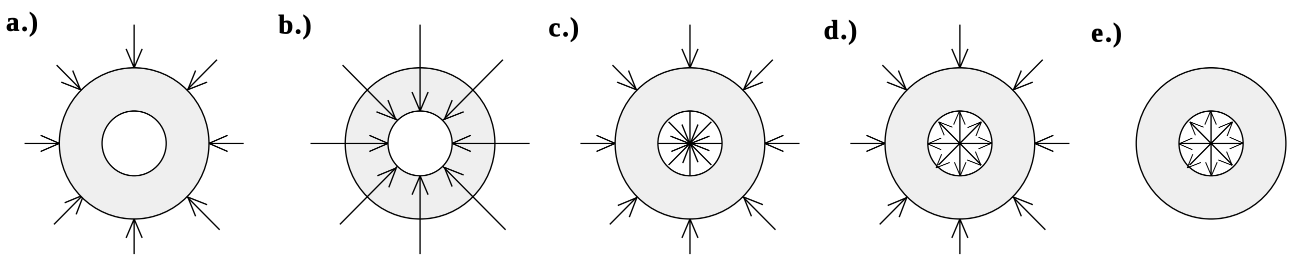
a.) The inductive reactance will go down and the impedance will go up. [To begin with, a power supply whose angular frequency is 377 radians/second (this was deduced by looking at the power supply in the sketch) has a frequency of 60 hertz ((377 rad/sec) = 2π(60 Hz)). That means that the frequency is doubled. Knowing that, there is a quick and easy way to do this problem and a more mathematically challenging way. THE SHORT WAY: Inductors are low pass filters. That means they are amenable to passing low frequency signals but will not pass high frequency signals. That also means that their resistive nature increases as the frequency increases (the more resistance to charge flow, the less current you get). As the frequency has increased in this circuit, the resistive nature of the inductor has increased and the net impedance (the net resistive nature of the whole circuit) has increased. THE MATH WAY: In its most general form, the impedance expression is Z = $\sqrt{R_{net}{}^2 + (X_L - X_C)^2}$ ohms, where $X_L = 2\pi\nu L$ ohms (the inductance L has to be in henrys, not mH, etc.) and $X_C = \frac{1}{2\pi\nu C}$ ohms (the capacitance C has to be in farads, not mf or pf, etc.). In this problem there is no capacitance. As such, the impedance expression becomes $\sqrt{R_{net}{}^2 + (2\pi\nu L)^2}$. From this expression, it is obvious that as the frequency increases, both the inductive reactance and the impedance increases. This response is false.]

b.) The inductive reactance will go down and the impedance will go down. [Nope.]

c.) The inductive reactance will go up and the impedance will go up. [This is the one.]

d.) The inductive reactance will go up and the impedance will go down. [Nope.]

23.) If you place a charge -Q on a hollow conducting sphere, then levitate an equal charge +Q at the hollow's center, the electric field lines for the situation will look like:



[Commentary: This is a bit tricky. The +Q at the hollow's center will produce an electric field in the hollow (this eliminates Response a and Response b). The charge at the center is positive, so the field lines will be outward (this eliminates Response c). There will be no electric field inside the conductor because that's the way conductors are. (Note: The charge enclosed inside a Gaussian surface positioned inside the conductor must add to zero--for that to happen, -Q's worth of charge inside the conductor will be attracted to the surface of the hollow . . . this is caused by the electrostatic attraction between the conductor's electrons and the levitating charge +Q at the hollow's center . . . so the net charge inside the Gaussian surface is zero--I mention this to remind you of the mechanics of what is actually happening inside the conductor). What is happening outside the conductor? The total free charge in the system is the -Q placed on the conductor and +Q placed at the center. A Gaussian sphere whose surface is outside the conductor will have no net charge within it, so the net electric field evaluated on that surface will be zero and there should be no field lines outside the sphere. The correct response is Response e.]

24.) Which statement is true?

a.) Electric fields have the units of volts/coulomb. [The relationship E_x = -dV/dx suggests that the units for electric fields are volts/meter, not volts/coulomb. This response is false.]

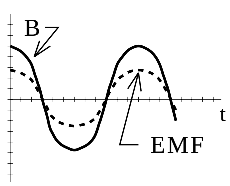
b.) Electrical potential vectors have the units of volts. [This is tricky. The units for electrical potential is volts, but electrical potentials are not vectors. This response is false.]

c.) Electrical potential energy has the units of volts. [Electrical potential energy is an energy quantity and has the units of energy, or joules. The fact that the words electrical and potential appear next to one another does not mean the author is alluding to voltage. You have to read closely to get the drift. This response is false.]

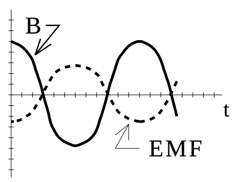
d.) None of the above. [This is the one.]

25.) A coil is placed in a changing magnetic field. A graph of the B-field is shown on each of the grids below. Due to the changing B-field, an induced EMF is generated in the coil. Which graph depicts the appropriate EMF function, given the B-field function?

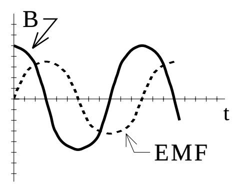
a.)



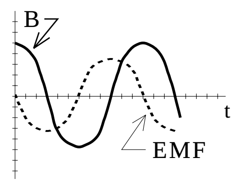
b.)



c.)

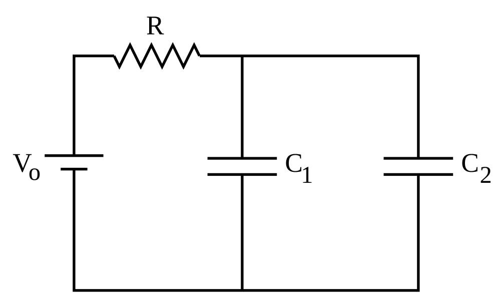


d.)



e.) None of these.

[Commentary: For a constant coil area and angle, the relationship between the changing magnetic field through a coil (hence, the changing magnetic flux through the coil) and the EMF that is set up as a consequence of that changing field is $\varepsilon = -(NA\cos\theta)\frac{dB}{dt}$. In other words, the EMF is proportional to minus the change of B with time. The slope of the B-field function at t = 0 is zero, so the EMF at that point in time is zero (this eliminates graphs a and b). Just a little past t = 0, the slope of the B-field function is negative getting larger, so the EMF should be positive getting larger. This eliminates graph d leaving graph c as the true response.]



26.) Enough time has passed for the capacitors in the circuit to fully charge. A dielectric (dielectric constant equal to 2) is slipped between the plates effectively doubling the capacitance of C_1. As a consequence:

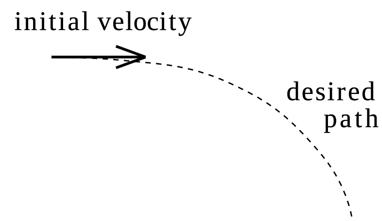
a.) The voltage across C_1 just after the change will halve. [The short answer: Just after, the charge will not have had time to change but the capacitance will have doubled, so $V_{c,new} = Q_1/(2C_1) = (1/2)(Q_1/C_1) = (1/2)V_o$. It would appear that the voltage across the capacitor just after the change is, indeed, half the voltage just before the change. This response is true. FOR A LITTLE MORE THINKING ABOUT THE QUESTION: At any given instant, the voltage across C_1 will equal the voltage across the power supply minus the voltage across R, or $V_C = V_o - iR$ (this follows from the fact that the voltage across the power supply will always be $V_o = V_c + iR$). When fully charged without the dielectric, there will be no current in the circuit, the voltage across C_1 will be V_o, and the charge on C_1 will be, say, Q_1. The reason C_1 doubles when the dielectric is placed between its plates is due to the fact that dielectrics diminish the effective electric field between the plates and, as a consequence, diminish the voltage across the plates (this diminishing of the net electric field is due to a Van der Waal's effect that polarizes charge in the dielectric's atomic structure creating a reverse electric field that fights the field produced by the free charge on the plates). In short, the initial effect of inserting a dielectric between the capacitor's plates is to drop the plate voltage. That, in turn, will draw current from the battery. The current flows until the plate voltage and the battery voltage are once again the same. In the process, the charge on the capacitor doubles. In any case, this response is true.]

b.) The capacitor C_1 charges and the power provided by the power supply during that charge-up is $.5CV^2$. [We have already established that the charge on the C_1 increases, so the first part of this response is true. Unfortunately, the energy provided to the circuit during the charge will not equal the power provided by the power source. Power is a measure of work per unit time being done at a particular instant. The $.5CV^2$ expression is for the total energy a capacitor holds when a voltage V is placed across the capacitor's plates. As power is not associated with energy but with energy per unit time, the latter part of this response is false.]

c.) The circuit's time constant decreases. [The time constant for a parallel combination is RC_{eq}. C_{eq} increases when a capacitor in a parallel combination is increased, so doubling C_1 should increase C_{eq}, the time constant should increase, and this response is false.]

d.) Both b and c. [Nope.]

e.) None of the above. [Nope.]

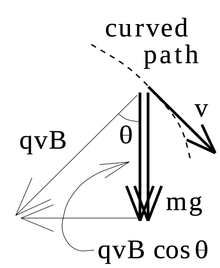


27.) A Star Fleet wannabe tries to accurately simulate the flight of an arrow of mass m and initial velocity v close to the earth's surface (i.e., in a gravitational setting). To do this, she eliminates gravity, puts a charge q on the arrow, and fires the arrow with an initial velocity v through a time-varying magnetic field. The path to be followed is shown in the sketch.

a.) The direction of the B-field must be downward and its magnitude must be mg/qv, where v is the velocity of the charged arrow at any arbitrary point in time. [The direction of B will not be in the direction of the magnetic force, which is downward at the beginning of the flight. In fact, those two variables are always perpendicular to one another. This response is false.]

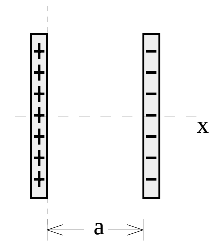
b.) The direction of the B-field must be into the page and its magnitude must be mg/qv, where v is the velocity of the charged arrow at any arbitrary point in time. [QvxB and the right-hand rule predict that the initial force on a positive charge moving to the right into a magnetic field oriented into the page (as this response suggests) will be directed upward. As the initial force must be downward, the B-field we are looking for must be oriented out of the page. This response is false.]

c.) The direction of the B-field must be out of the page and its magnitude must be mg/qv, where v is the velocity of the charged arrow at any arbitrary point in time. [This gives the correct magnetic field direction. What about the magnetic field magnitude? This is particularly sneaky. To begin with, can the geometric path of the arrow be simulated using a time varying magnetic field equal to mg/qv? Initially, the downward magnetic force qvB could take the place of the downward gravitational force mg. But once into the flight, the direction of the magnetic force will be perpendicular to the velocity vector--a direction that is not strictly downward. In fact, the function that would have to be used to simulate the effect of mg would have to be something like $qvB\cos\theta$ (see accompanying sketch). But that's not the only problem with this analysis. Along with providing the correct force magnitude, an accurate simulation would also require the arrow's velocity to increase as the simulation progresses. In this set-up, the velocity magnitude never gets larger

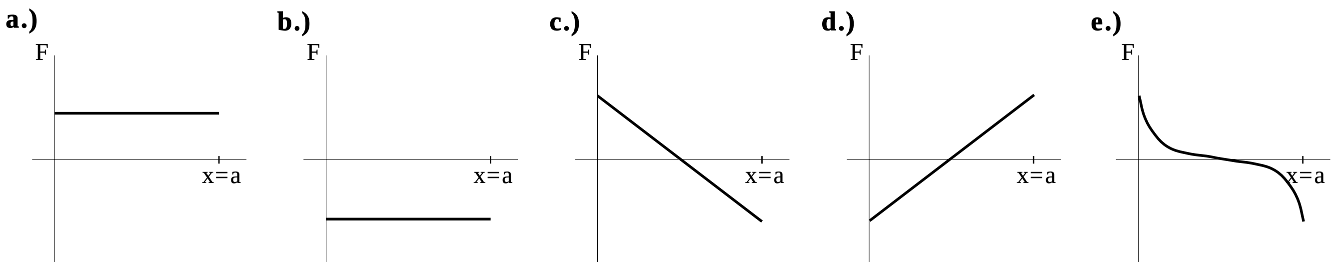


than the initial velocity. Why? Because MAGNETIC FIELDS DO NOT CHANGE VELOCITY MAGNITUDES, THEY ONLY CHANGE VELOCITY DIRECTIONS. As such, this response is doubly false.]

d.) None of the above. [This is the one.]



28.) Oppositely charged parallel plates are set up and the force on an electron placed at various points between the plates is recorded. The graph of the Force vs. Position function for the region between the plates looks like:



[Commentary: The electric field between oppositely charged parallel plates is essentially constant (at least if you stay away from the edges). That means that the force per unit charge available at any point will not be different from point to point. In short, it doesn't matter where you are, the force on the electron should be the same. If that be the case, the electron will feel a force directed toward the positive plate (that is in the -x direction, according to our sketch), and the force magnitude should be constant. The response that does the job here is Response b.]

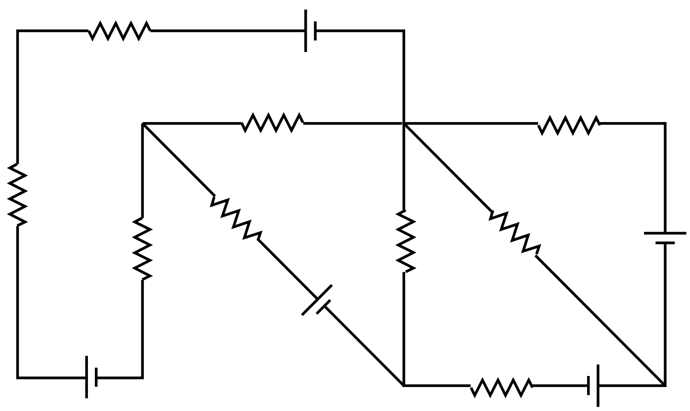
29.) A variable power supply produces an AC voltage equal to 5 sin ($4\pi t$) volts. The power supply is placed in series with a 100 Ω resistor and an AC ammeter. The ammeter will read:

a.) Zero amps because the charge carriers in an AC circuit don't go anywhere, they just jiggle back and forth due to the alternating voltage and its associated alternating electric field. [In DC circuits, current is defined as the amount of charge that passes by a particular point per unit time. Its units are coulombs per second, and DC ammeters are designed to measure that charge count. In AC circuits, charge carriers do, indeed, go nowhere macroscopically as they jiggle back and forth driven by the alternating electric field generated by the power supply's alternating voltage. But that doesn't mean AC ammeters always read zero amps (in fact, such meters would be obviously useless). In fact, what an AC ammeter reads is the RMS current--the current that would, in a DC circuit, provide the same power in the circuit as does the AC source. Ohm's Law still works in AC circuits, but the values used are RMS values. In other words, $V_{RMS} = i_{RMS}R$, or i_{RMS} = [.707(5 volts)]/(100 Ω) = .035 amps. This response is false.]

b.) .05 amps. [If you used the amplitude of the voltage function instead of the RMS value of the voltage in Ohm's Law, you got this incorrect response.]

c.) .035 amps. [This is the one.]

d.) .07 amps. [Nope.]



30.) For the circuit shown:

a.) There are 3 nodes, 6 branches, and 11 loops in this circuit. [A node is a junction--a place in the circuit where the current splits up or combines with other currents. There are 4 nodes in this circuit. A branch is a section in which a current is the same. There are 7 branches in this circuit. A loop is any closed path (i.e., to define a loop, simply start at some point and proceed through branches until you return to the start point). There are 9 loops in this circuit. This response is false.]

b.) There are 4 nodes, 7 branches, and 9 loops in this circuit. [This is the one.]

c.) There are 4 nodes, 8 branches, and 11 loops in this circuit. [If you retraced branches more than once--not a kosher move--you got 11 loops. This response is false.]

d.) None of the above. [Nope.]

31.) A 2 kg mass has a 10 coulomb charge on it. It is placed at Point A in a constant electric field and released from rest, freely accelerating to Point B. The electrical potential of B is 40 volts. The mass's velocity at B is 4 m/s. Assuming the charge continues to accelerate on to a third point (call it Point C) where the electrical potential is 80 volts, what is the charge's velocity at that point?

a.) Approximately 19.5 m/s. [This is a conservation of energy problem. To use conservation of energy, all we need are two points that we know something about (or want to know something about). In this case, Points B and C will do the trick (that means that we don't care what happened between A and B--we start with point B as our initial point and go from there). With this, we can write: $KE_B + U_B + W_{ext} = KE_C + U_C$. Expanding this, we get:

$$.5mv_B^{\ 2} + qV_B + 0 = .5mv_C^{\ 2} + qV_C$$

$$\Rightarrow \quad .5(2\text{ kg})(4\text{ m/s})^2 + (10\text{ coul})(40\text{ volts}) = .5(2\text{ kg})v_C^{\ 2} + (10\text{ coul})(80\text{ volts})$$

$$\Rightarrow \quad v_C = \sqrt{-384\text{ m/s.}}$$

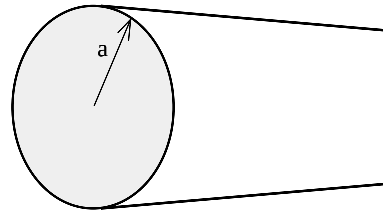
If you ignored the negative sign (shame on you), you got approximately 19.5 m/s. If, on the other hand, you noticed the negative sign, you realized that the math was telling you that the charge would never reach a point C where the electrical potential was 80 volts under the conditions of the problem. Why not? Think about it. Positive charges accelerate from high voltage to low voltage. This positive charge is going against the field (from low voltage at 40 volts to high voltage at 80 volts), which means that it is slowing down. It is not inconceivable, given the fact that its velocity at B is only 4 m/s, that it would stop short of the 80 volt point and accelerate back away from that point. That, evidently, is what is happening here. This response is false.]

b.) Approximately -19.5 m/s. [The square root of -384 is not -19.5 (approximation or no). The square root of a negative number is an imaginary number. This response is false.]

c.) There is not enough information to determine the answer to this problem. [No, there is enough information to come to conclusions about this problem . . . and the conclusion is that the charge will never reach C. This response is false.]

d.) This problem is impossible to answer with a number because the charge never reaches a point where the electrical potential equals 80 volts. [This is the one.]

32.) A solid cylinder of radius a has a volume charge density shot through it of $k_1 r$, where $k_1 = 10^{-10}$ with appropriate units, a = 1 meter, and the constant ε_o is approximated as 10^{-11} coul^2/(nt·m^2). The electric field at x = a/2 will be:



a.) .20 nt/coul. [You just have to do the problem. Gauss's Law yields:

$$\int \mathbf{E} \bullet d\mathbf{S} = \frac{q_{\text{enclosed}}}{\varepsilon_o}$$

$$\Rightarrow \quad E(2\pi r L) = \frac{\int \rho dV}{\varepsilon_o}$$

$$\Rightarrow \quad E = \frac{\int_{c=0}^{r} (k_1 c)[(2\pi c\, dc)L]}{(2\pi r L)\varepsilon_o}$$

$$\Rightarrow \quad E = \frac{k_1 \left[\frac{c^3}{3}\right]_{c=0}^{\frac{a}{2}}}{\varepsilon_o r}$$

$$\Rightarrow \quad E = \frac{k_1}{\varepsilon_o\left(\frac{a}{2}\right)}\left(\frac{\left(\frac{a}{2}\right)^3}{3}\right)$$

$$\Rightarrow \quad E = \frac{(2.5)}{(3)} = .83 \text{nt/coul.}$$

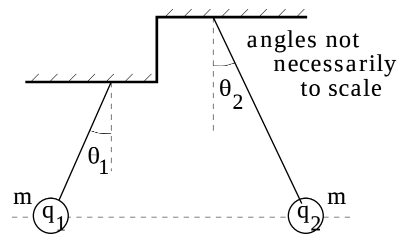
According to the calculation, this response is false.]

b.) .65 nt/coul. [Nope.]

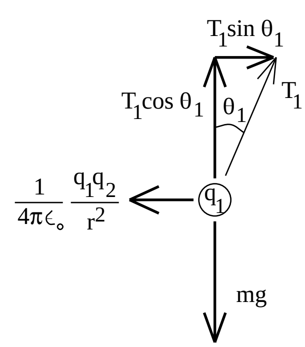
c.) .83 nt/coul. [This is the one.]

d.) None of the above. [Nope.}

33.) A charge q_1 is placed on a mass m that is suspended from a string. A second charge q_2 is placed on an identical mass m suspended on a second string. The two strings are attached to the ceiling as shown in the sketch.



a.) $\theta_1 = \theta_2$. [What governs the angle is not the string length, it is the net force on the strings. If the masses are the same, which they are, and if the electric forces are the same, which they must be (N.T.L.), and as both are in equilibrium (i.e., acceleration is zero in both cases), the tension in both lines must be the same. That is, looking at the f.b.d., we can write:



ΣF_y :

$$T_1 \cos\theta_1 - mg = ma_y$$
$$\Rightarrow \quad T_1 \cos\theta_1 - mg = 0 \qquad (\text{as } a_y = 0)$$
$$\Rightarrow \quad T_1 = \frac{mg}{\cos\theta_1}.$$

ΣF_x :

$$T_1 \sin\theta_1 - \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2} = ma$$
$$\Rightarrow \quad T_1 \sin\theta_1 = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2} \qquad (\text{as } a_x = 0).$$

Substituting in to eliminate the T_1 term yields the expression:

$$\frac{mg}{\cos\theta_1}\sin\theta_1 = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}$$
$$\Rightarrow \quad mg\tan\theta_1 = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}.$$

As m is the same for both masses, and as q_1 and q_2 in the electric force expression will show up whether the f.b.d. is on the left mass or the right mass, the expression written above is true for both masses As such, the angle must be the same in each case and this response must be true.]

b.) $\theta_1 < \theta_2$. [Nope.]

c.) $\theta_1 > \theta_2$. [Nope.]

d.) The relationship between the angles can't be determined with the information given. [Nope.]

34.) A capacitor and inductor are placed in series with a resistor and an AC power supply. The frequency of the power supply is tuned to the resonant frequency for the circuit. The frequency is then quadrupled.

a.) The capacitive reactance will increase, the inductive reactance will decrease, but between the two the larger change will occur to the inductive reactance. [The capacitive reactance is equal to $\frac{1}{2\pi\nu C}$ and the inductive reactance is equal to $2\pi\nu L$. Quadrupling the frequency will decrease the capacitive reactance and increase the inductive reactance. From that alone, this response is false.]

b.) The capacitive reactance will increase, the inductive reactance will decrease, but between the two the larger change will occur to the capacitive reactance. [From above, this first part of this response makes the whole thing false.]

c.) The capacitive reactance will decrease, the inductive reactance will increase, but between the two the larger change will occur to the inductive reactance. [From above, the first part of this is true. As for the second part: In RLC circuits, current only flows when the power supply is operating at or near the resonant frequency of the circuit. The reason? Above that frequency, the inductor cuts out current flow. Below that frequency, the capacitor cuts out current flow. Quadruple the frequency in this situation and the current will drop to zero. At resonance, $\frac{1}{2\pi\nu C}$ and $2\pi\nu L$ are the same value. When the frequency goes up by a factor of four, the inductive reactance is multiplied by four and the capacitive reactance is divided by four. The largest change will, therefore, be in the inductive reactance. This response is true.]

d.) The capacitive reactance will decrease, the inductive reactance will increase, but between the two the larger change will occur to the capacitive reactance. [Nope.]

35.) The average power delivered to a flashbulb is 500 watts when a 2000 volt source fully charges the system's capacitor. If the flash lasts .08 seconds, the capacitance of the capacitor must be somewhere in the vicinity of:

a.) 10^{-9} farads. [The average power tells you the average rate at which energy is dumped into the circuit. At a rate of 500 watts, the amount of energy dissipated by the resistor in .08 seconds will be Pt = (500 joules/sec)(.08 sec) = 40 joules. That energy came from the capacitor, the energy relationship of which is $.5CV^2$. If we assume that all of the energy is dumped in .08 seconds, we can equate the energy dumped (40 joules) to the energy content of the capacitor ($.5CV^2$) and write (40 joules) = .5C(2000 volts)^2, or C = 20×10^{-6} farads. This response is off by a factor of approximately 1000, which is to say that this response is false. NOTE: As the possible answers are separated by a factor of one-thousand each, we could have done this problem by using some technically inappropriate mathematical assumptions that would still have brought us into the ball park of the correct capacitance. Specifically, the time constant for an RC circuit tells us approximately how fast the capacitor/resistor combination will charge up or discharge if given free reign. In this case, we need a time constant that dumps almost all of its energy in .08 seconds. As 87% of the energy will be dumped in time 2τ and 95% will be dumped in time 3τ, we will use 2τ for our calculation. Doing so yields (.08 seconds) = 2RC. To complete this calculation, we need to determine the resistance R in the circuit. Just as the capacitor begins its discharge, the 2000 volts across its plates are also across the resistor (the two are in parallel). If we could determine the initial current, we could determine a value for R. We can't quite do that--all we know is the average power--but using that we could write $P_{avg} = i_{avg}V$. Doing so yields (500 watts) = (2000 volts)i_{avg}, or i_{avg} = .25 amps. This isn't the initial current--the current dampens out as time goes on and less and less charge is on the capacitor's plates, but because we are looking for a ball park value--we could assume that the initial current was twice the average current, or .5 amps. Given that somewhat dubious assumption, the ball park resistance is found to be R = $V/i_{initial}$ = (2000 volts)(.5 sec) = 4000 Ω Using that value, our two time constants expression becomes (.08 seconds) = 2RC = 2(4000 Ω)C. From this, we get a ball park value of C = 40×10^{-6} farads. This is not the real value of C, but it gives us enough information to determine the correct response to the question. The moral of the story? GUESTIMATING IS A PERFECTLY GOOD WAY TO ANALYZE SITUATIONS.]

b.) 10^{-6} farads. [This is the one.]

c.) 10^{-3} farads. [Nope.]

d.) None of the above. [Nope.]

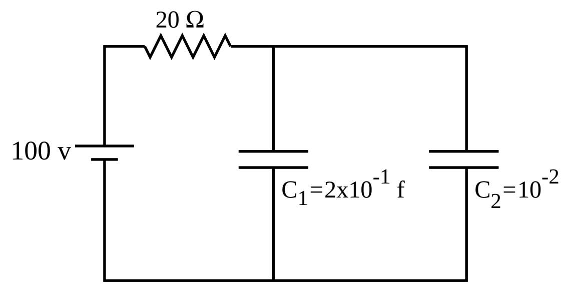
36.) The inductance of a coil is .5 mH. The current change that would be required to induce a 3 volt potential across the coil's leads is:

a.) 1.5 amps/second. [The 3 volt potential across the leads refers to the EMF induced in the coil due to the change in current. The relationship between a current change and the induced EMF that is generated due to that change is $\varepsilon = -L\frac{di}{dt}$, where L is the inductance of the coil. For this case, we can write (3 volts) = -(.5x10^{-3} henrys)(di/dt), or di/dt = 6x10^{3} amps/second--a seriously big current change (the maximum value for current (per circuit breaker) in most homes is 15 to 20 amps). This response is false.]

b.) .015 amps/second. [Nope.]

c.) 6 amps/second. [If you didn't convert from millihenrys to henrys, you got this incorrect answer.]

d.) None of the above. [This is the one.]



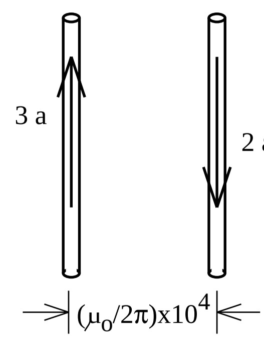
37.) At the instant shown, the current through the 20 Ω resistor is 2 amps. The charge on C_2 is:

a.) .6 coulombs. [The sum of the voltage drops across C_1 and R have to equal the voltage across the battery. This yields (100 volts) = (2 amps)(20 Ω) + V_1, or V_1 = 60 volts. As the two capacitors are in parallel, the voltage across C_2 must also be 60 volts. As the charge on a capacitor is Q = CV, we can write Q = (10^{-2} f)(60 v) = .6 coulombs. This response is true.]

b.) 1.2 coulombs. [Nope.]

c.) 2.4 coulombs. [Nope.]

d.) None of the above. [Nope.]



38.) The force per unit length a 3 amp wire (call this wire 1) feels due to the presence of a 2 amp wire (call this wire 2) will:

a.) Equal 3 newtons per meter and will be 3/2 the force the 2 amp wire feels due to the presence of the 3 amp wire. [Jumping directly to the second part of this response: According to Newton's Third Law, for every action in the universe there must be an equal and opposite reaction. That observation comes into play here because the force wire 1 feels due to the presence of the magnetic field generated by wire 2 must be equal and opposite the force wire 2 feels due to the presence of the magnetic field generated by wire 1. This response is false.]

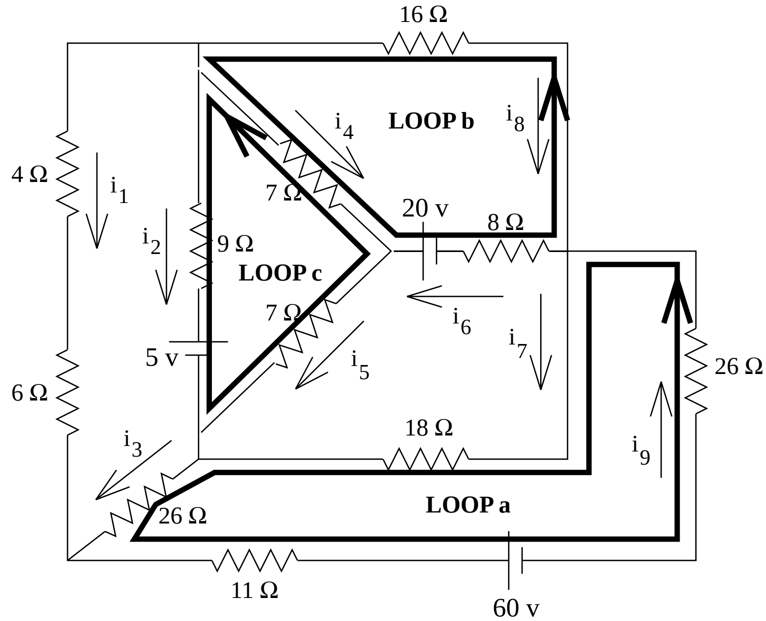
b.) Equal 6 newtons per meter and will be 2/3 the force the 2 amp wire feels due to the presence of the 3 amp wire. [This also violates Newton's Third Law. This response is false.]

c.) Equal 9 newtons per meter and will be the same as the force the 2 amp wire feels due to the presence of the 3 amp wire. [Newton's Third Law isn't violated in this response, so let's look farther. The magnitude of the magnetic field produced by the 2 amp wire is $\frac{\mu_o i}{2\pi r}$ =

$$\frac{\mu_o(2\ amps)}{2\pi\left[\frac{\mu_o}{2\pi}x10^4\right]} = 2x10^{-4}\ teslas.$$

The force wire 1 feels due to the presence of wire 2 will equal iLxB. Because the angle between the current flow and wire 2's magnetic field is 90^o, the sine of the angle will equal one. That means the magnitude of the magnetic field per unit length will equal iLB/L, or (3 amps)(2x10^{-4} teslas) = 6x10^{-4} newtons. This response is way off.]

d.) None of the above. [This is the one.]



39.) For the circuit shown:

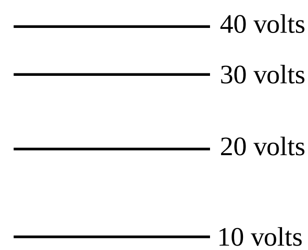
a.) $-37i_9 - 18i_7 - 26i_3 = 60$. [The loops used for all of the equations written for this question are highlighted in the auxiliary sketch. Summing the voltage changes around LOOP a, we get $-26i_9 - 18i_7 - 26i_3 - 11i_9 - 60 = 0$. Combining like terms and placing the 60 volt quantity on the right side of the equal sign, we get $-37i_9 - 18i_7 - 26i_3 = 60$. This response is true. Are there others?]

b.) $16i_8 - 7i_4 + 8i_6 = -20$. [LOOP b yields $16i_8 - 7i_4 -20 + 8i_6 = 0$. This response would work if the sign of the 20 volt term was correct. This response is false.]

c.) $7i_4 - 9i_2 + 7i_5 = 5$. [LOOP c yields $7i_4 - 9i_2 - 5 + 7i_5 = 0$. This matches the response and is true. Are there other possibilities?]

d.) There are at least two correct loop equations above. [A nasty thing to do, making you check each loop instead of finding the first correct one and stopping there. In any case, this response is true.]

e.) None of the above. [Nope.]



40.) In a 10 second period, a -2 coulomb charge is made to move with a constant velocity from the top to the bottom of the electrical potential field shown.

a.) The work the field does is positive and the magnitude of the electric field increases as one proceeds upward. [To determine whether the work done is positive or negative, we must first determine the direction of the electric field. An electric field's direction is defined as the direction a positive test charge will accelerate if put in the field. As free positive charge always migrates from high electrical potential to low electrical potential, the electric field in this case must be downward. A positive charge will, therefore, have positive work done on it as it moves "from the top to the bottom." Unfortunately, this charge is not positive, it is negative. Negative charges act in a way that is opposite to that of positive charges, so in this case the work done by the field will be negative. This response is false.]

b.) The work the field does is negative and the magnitude of the electric field increases as one proceeds downward. [From above, the first part of this response is true. As for the second part, a big electric field will have incremental equipotential lines that are very close together (when an electric field is big, a charge in it will experience a big potential energy change with only a small change of position). As electric field intensity is related to how spread out the electrical potential lines are, the electric field in this case will be larger at the top and smaller at the bottom. This response is false.]

c.) The work the field does is positive and the magnitude of the electric field increases as one proceeds upward. [From above, this is false.]

d.) None of the above. [This is the one.]